Outcome of Physical Therapy Intervention on Ventilator Weaning and Functional Status

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Our study aimed to understand the characteristics of ventilator dependence in patients at a respiratory care center and the potential effects of physical therapy on ventilator weaning and patients' functional status. Prospective data collection consisted of the following: (1) demographic data, including name, gender, age, diagnosis, the Acute Physiology and Chronic Health Evaluation as a severity of the disease, modified Glasgow Coma Scale, mobility at the time of admission, and days of hospitalization; (2) Rapid shallow breathing index (RSBI) as a predictive indicator of ventilator weaning, including indicators of ventilator weaning were collected from the respiratory flow sheet; and (3) Barthel index. Between July 1 and December 31, 2007, 126 patients were admitted to the respiratory care center, and those who required mechanical ventilation for more than 14 days were enrolled. Fifty-five subjects received physical therapy. The RSBI in patients who received physical therapy was 75.7 ± 37.9 before therapy and 80.0 ± 48.5 afterwards, while the Barthel index increased from 0.8 ± 1.4 to 1.9 ± 2.5 ($p < 0.05$). The RSBI decreased as time of physical therapy lengthened, but not significantly ($r = 0.12$, $p = 0.44$). The success rate of ventilator weaning in patients receiving physical therapy intervention versus non-physical therapy intervention was 58.2% and 40.9%, respectively. The results indicated that lengthening the physical therapy intervention time enhanced the ventilator weaning success rate while mobility was not affected ($r = -0.11$, $p = 0.41$). Physical therapy may be offered to ventilator-dependent patients in line with their individual needs to improve or maintain basic mobility.

Key Words: mobility, physical therapy, respiratory care center, weaning from ventilator
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Dependence on long-term mechanical ventilation following the resolution of acute illnesses or multiple chronic diseases is a serious healthcare problem in Taiwan. According to statistical data from the Bureau of Taiwan National Health Insurance (NHI), 61,708 patients used ventilators continuously for over 21 days in 2006 and were classified as either critically injured or diseased. Associated health expenses reached an astonishing figure of 13 billion New Taiwan Dollars [1]. In order to reduce the unnecessary utilization of mechanical ventilation and to limit medical resources, the NHI introduced the prospective payment system in 1998. The Integrated Delivery System (IDS) is a program for long-term mechanical respiratory care.

IDS integrates different levels of respiratory care and consists of intensive care units, respiratory care centers (RCCs), respiratory care wards, and home

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care. According to the IDS system, during the first 21 days of intensive care unit admission, if patients cannot be weaned successfully from the mechanical ventilator, then they will be transferred to a RCC for further weaning. If these patients still cannot be weaned from the ventilator after 42 days, then they will be transferred to the next stage of care, either a respiratory care ward or home care.

The primary goal of the RCC is to handle the patients' immediate problems and to facilitate ventilator weaning. Respiratory muscles play a critical role in balancing ventilatory demand and capacity. Nonetheless, during ventilator weaning, patients often showed signs of muscle fatigue and skeletal-muscular soreness, which are consequences of restricted physical activity and electrolyte abnormalities [2,4]. Physical therapy (PT) plays an imperative role in improving overall mobility functions, restoring respiratory and physical sovereignty, and reducing complications caused by being bedridden for long periods. Moreover, PT with training of the respiratory muscles to improve muscle strength and endurance may be a useful clinical intervention in weaning patients [5]. Unfortunately, only 3.3% of RCC patients receive PT due to the restrictive nature of the reimbursement program from the NHI [6]. Therefore, the focus of this research was placed on understanding the characteristics of ventilator dependence in patients at the RCC and the potential effects of PT on ventilator weaning and patients' functional status. The conclusions of the study serve as references for future medical evidence and clinical care.

Methods

Between July 1 and December 31, 2007, data was collected from 126 patients, who admitted to the RCC and required mechanical ventilation for more than 14 days. After being evaluated and determined as being in a stable condition by physicians, patients were given PT prescriptions tailored to fit the individual's needs by physical therapists. The 30-minute PT sessions, including abdominal breathing training, respiratory muscle weight training, passive and active joints exercises, upper and lower limb exercises, and progressive mobility training were conducted once a day, five times per week. Abdominal breathing training contained three sets of exercises with 10 repetitions for each exercise. Respiratory muscle weight training was based on the abdominal breathing exercises, and a sandbag of 1–2 kg was placed on the upper abdomen, with 10 repetitions per set for three sets. Joint exercises were performed 10 times on each joint, followed by the upper or lower limb exercises according to the patients' condition, with 10 repetitions per set for three sets. If the subject was suitable for progressive mobility training, the exercises were conducted in a sitting, standing or walking position. Those patients not receiving physical therapy (non-PT group) had routine passive joint exercises aided by primary nurses for a session of 5–10 minutes, twice a day.

The protocols were reviewed and approved by the Institutional Review Board of the Kaohsiung Medical University Hospital. The data collection consisted of the following: (1) demographic data; (2) predicative indicator of ventilator weaning (RSBI); and (3) Barthel index (BI). Patient demographic data included name, gender, age, diagnosis, the Acute Physiology and Chronic Health Evaluation (APACHE II) as a severity of the disease, modified Glasgow Coma Scale, mobility at the time of admission, and days of hospitalization. Respiratory parameters, including indicators of ventilator weaning were collected from the respiratory flow sheets. The patients were divided into six categories: (1) chronic diseases such as chronic obstructive pulmonary disease, pneumonia and asthma; (2) resolution of acute lung injuries and their chronic sequelae, including cardiogenic pulmonary diseases and post-surgery complications; (3) neuromuscular diseases, including stroke, spinal cord injury, post-brain surgery and motor neuron disease; (4) cardiovascular diseases, including heart failure, cardiac arrhythmia and coronary disease; (5) septicemia or drug poisoning; and (6) cancer. The patients' mobility evaluation was performed by means of the Chinese edition of the BI modified by Collin and conducted by visual observations or patient inquiry. The BI, published by Mahoney and Barthel in 1965, has been primarily used to evaluate the life functions of neuromuscular or musculoskeletal patients. Its reliability has been recognized by evaluators, and it is closely correlated to patients' health status [7]. Previous research has shown that the evaluation of ventilator-dependent patients' daily lives and quality of life, the mobility score, the total Barthel score and Functional Independence Measure are strongly correlated ($r = 0.877$ and 0.729, $p < 0.001$) [2]. There are 10 items regarding daily living in the BI, each item in a three-ordinal-number format

ranging from 0 to 2 points with a total score of 0–20. The RSBI, published by Yang and Tobin in 1991, was used as the index for observing respiratory muscle failure and predicting the ventilator weaning outcomes [8]. The ratio was calculated by dividing the tidal volume with the respiratory rate. If the ratio was ≤105, the probability of weaning from the ventilator would be higher [8,9].

Study results were presented as frequency, percentage, mean±standard deviation for categorical and continuous variables. To compare various variables between the PT and non-PT groups, the χ^2 test was used for categorical variables, and two-sample *t* tests were used for continuous variables. Paired *t* tests were used to compare the changes in RSBI and BI before and after PT. Pearson's correlation coefficients were used to reveal the linear relationship between RSBI and BI with time of PT. A *p* value of less than 0.05 was considered statistically significant. Statistical analysis was performed using JMP 6.0.0 software (SAS, JMP, version 6.01, Cary, NC, USA).

Results

One hundred and twenty-six patients, aged 20–95 years (mean=68.9±16.1 years) were admitted to the RCC between July 1 and December 31, 2007. The APACHE II was 16.4±6.5 and the Glasgow Coma Scale was 7.7±3.4. Most of the patients (48/126, 38.1%) suffered from chronic respiratory failure that was derived from an episode of acute lung injury. Seventy-one (56.3%) patients had undergone a tracheotomy at the time of admission. The average number of days of using a ventilator before admission was 20.4±6.6. Upon RCC admission, the number of ventilator days and the length of stay in the RCC was 16.2±12.1 and 19.9±11.7, respectively (Table 1). Among the patients, 61 (48.4%) were successfully weaned from ventilators.

The data pool was divided into PT and non-PT. There were no significant differences between these two groups in age, gender, Glasgow Coma Scale, tracheotomy, days of ventilator use, days of hospitalization, ventilator mode or diagnosis. There was, however,

Table 1. Correlation between demographic data of patients receiving physical therapy, ventilator weaning and mobility*

Variables	Total (*n*=126)	PT (*n*=55)	Non-PT (*n*=71)	χ^2 or *t*	*p*
Age (yr)	68.9±16.1	66.9±14.1	70.5±17.3	1.25	0.213
Gender, male	73 (57.9)	34 (61.8)	39 (54.9)	0.60	0.437
APACHE II	16.4±6.5	15.0±6.5	17.5±6.3	2.23	0.028
Glasgow Coma Scale	7.7±3.4	7.7±3.0	6.9±2.5	1.47	0.144
Tracheotomy	71 (56.3)	39 (58.2)	32 (54.9)	0.13	0.715
MV period before RCC (d)	20.4±6.6	21.6±8.3	19.4±4.8	1.72	0.088
MV period in RCC (d)	16.2±12.1	16.5±11.8	15.9±12.4	0.29	0.769
Total MV period (d)	37.5±16.4	39.9±16.9	35.6±15.8	1.45	0.151
Length of stay in RCC (d)	19.9±11.7	22.1±11.4	18.3±11.8	1.81	0.073
MV mode					
Pressure control	31 (26.0)	18 (33.3)	13 (20.0)	4.27	0.119
SIMV+pressure support	37 (31.1)	18 (33.3)	19 (29.2)		
Pressure support	51 (42.9)	18 (33.3)	33 (50.8)		
Underlying disease					
Lung disease	48 (38.1)	20 (36.4)	28 (39.4)	2.03	0.845
Post-surgery	5 (4.0)	2 (3.6)	3 (4.2)		
Neuromuscular disease	25 (19.8)	9 (16.4)	16 (22.5)		
Cardiac disease	20 (15.9)	9 (16.4)	11 (15.5)		
Sepsis and Other	16 (12.7)	8 (14.6)	8 (11.3)		
Cancer	12 (9.5)	7 (12.7)	5 (7.0)		
Weaned	61 (48.4)	32 (58.2)	29 (40.9)	3.73	0.054
RSBI	84.4±44.0	88.7±53.9	80.7±33.8	0.81	0.420
BI	0.4±0.8	0.6±0.9	0.2±0.5	3.00	0.004

*Data presented as mean±standard deviation or *n* (%). PT=physical therapy; MV=mechanical ventilator; APACHE II=Acute Physiology and Chronic Health Evaluation; SIMV=synchronized intermittent mandatory ventilation; RSBI=rapid shallow breathing index; BI=Barthel Index.

Table 2. Outcomes of physcial therapy patients ($n = 55$)

Variables	n (%)
Period of PT (d)	
≤7	4 (7.3)
8–14	22 (40.0)
15–20	9 (16.4)
≥21	20 (36.4)
Average PT period (d)	14.8±7.9
PT (multiple item s)	
Passive range of motion exercise	37 (23.7)
Active range of motion exercise	25 (16.0)
Upper limb exercise	28 (17.9)
Lower limb exercise	27 (17.3)
Breathing muscle training	21 (13.5)
Progressive mobility	18 (11.5)

PT = Physical therapy.

Table 3. Analysis of ventilator weaning with physical therapy intervention and patients' mobility ($n = 55$)*

	Before PT	After PT	t
RSBI	75.7±37.9	80.0±48.5	0.540
BI	0.8±1.4	1.9±2.5	0.004†

*Data presented as mean±standard deviation; †$p < 0.05$. PT = physical therapy; RSBI = rapid shallow breathing index; BI = Barthel Index.

a noticeable difference in disease severity ($\chi^2 = 2.23$, $p = 0.028$), indicating that the severity (APACHE II score) in the PT group was lower than that of the non-PT group (15.0 *vs.* 17.5). A significant difference was also shown in BI ($t = 3.00$, $p = 0.004$), signaling that the mobility (BI) in the PT group was higher than that of the non-PT group (0.6 *vs.* 0.2). No significant differences were observed in the weaning rate between PT and non-PT (Table 1).

Fifty-seven (45.2%) of the patients admitted into the RCC were conscious, 55 (43.7%) of whom notified therapists and received PT. Twenty of the 55 patients (36.4%) stayed in therapy for over 21 days. PT exercises were mostly in the passive range of motion exercises ($n = 37$, 23.7%), followed by upper limb exercises ($n = 28$, 17.9%) as shown in Table 2. The RSBI was 75.7±37.9 among patients before PT and 80.0±48.5 afterwards. A further t test demonstrated no obvious difference ($t = 0.540$, $p = 0.57$), indicating that PT and the ventilator weaning index were not statistically different. Thirty-two (58.2%) patients in the PT group versus 29 (40.9%) in the non-PT group were successfully weaned from ventilators. Most of these patients in the PT group had respiratory diseases. The BI increased from 0.8±1.4 to 1.9±2.5 (Table 3). A further t test revealed obvious differences ($t = 0.004$, $p = 0.01$), showing that PT helped in restoring patients' mobility. Further statistical analysis on the correlation of time of PT and ventilator weaning/mobility indicated that the length of time in PT and RSBI was not significant ($r = 0.12$, $p = 0.44$). Although the success rate of weaning from ventilators in this study reached 58.2%, the results did not exhibit any correlation with mobility ($r = –0.11$, $p = 0.41$), indicating that the patients' mobility failed to show improvements as time in PT increased.

Discussion

The success rate of ventilator weaning depends on various factors, namely respiratory function, neuromuscular ability, oxygenation conditions, cardiopulmonary function and psychological factors [10]. A majority of patients, dependent on long-term use of ventilators have a certain degree of underlying ventilator-related infections as complications of pulmonary diseases and surgery, which increases the difficulty of ventilator weaning. It has been documented in past clinical studies that in order to help wean patients from ventilators, medical personnel and respiratory therapists, in addition to giving patients different medical prescriptions and ventilator weaning plans, have also introduced PT to effectively increase the strength of the respiratory muscles and improve physical activity functions and quality of life [11,12]. Jiang et al collected data from numerous hospitals between July and December of 2001, and only 153 out of 4,001 patients (3.8%) who used ventilators applied for PT [4]. Out of the 4,001 patients, 997 (24.9%) had used a ventilator for over 21 days, and 3.3% had received PT at a medical center. Of all the patients who undertook PT, 62.4% had respiratory diseases [5]. Their conclusions coincide with the results of our study in which the majority of patients, mostly chronic bedridden elderly patients with pneumonia, had respiratory diseases (20/55, 36.4%). This study explored the effect of ventilator weaning on patients at a RCC with PT intervention and concluded that no correlation was found, which matches the result of past studies [13]. Hu and Lee [13] adapted

inspiratory muscle training in 2006. They selected 30 ventilator-dependent patients who had been using ventilators continuously for over 21 days and had undergone tracheotomies without any complications. These patients were divided randomly into a training group and a control group. The training group received 4 weeks of respiratory muscle training and showed significant improvements in maximum inspiratory pressure and inspiratory muscle strength over the patients in the control group. However, the success rates of ventilator weaning in both groups failed to demonstrate a statistical difference, and the patients in these two groups failed to be weaned from ventilators after multiple attempts. Most of them had used ventilators for nearly 200 days. A decrease in respiratory muscle strength and endurance due to long-term dependence on ventilators might have been the reason why these two groups failed to meet the expected statistical difference in the weaning success rate. The patients in our study had used ventilators for a much shorter period. However, past studies have indicated that the probability of weaning from ventilators decreases due to waning of the strength of respiratory muscles and limbs once patients have used ventilators for over 7 days [14]. Some studies have shown that respiratory muscle training assists patients in being weaned from ventilators [15,16], but the number of case studies is insufficient to provide enough scope for inference. Research that monitors the effects of PT over a long period of time has rarely been conducted in the past. However, early intervention of PT plays a crucial role in preventing complications in long-term bedridden ventilator-dependent patients [6]; which deserves the attention of clinical medical personnel. Fifty-five patients in this study, after being admitted into the RCC, actually received PT related to ventilator weaning training. The average time of continuous PT training was 14.8 days, and 20 patients remained in the program for 20 days or more. The American Association for Respiratory Care suggests a continuous 12 hours per week exercise program for a minimum of 6 weeks in order to see results [17]. In compliance with the restrictions imposed by the NHI system, patients in our ward that could not be weaned from ventilators 42 days after being admitted into the RCC had to be transferred to the respiratory care wards of other regional hospitals. Those who were successfully weaned were required to be transferred to regular wards or back home, which made it impossible to monitor the effects of PT over an extended period of time.

Our study showed that the patients' BI was elevated to 1.9 ± 2.5 following admission to the RCC, compared with 0.8 ± 1.4 before admission, and that some patients demonstrated improved mobility. However, the results did not continue to improve as the treatment time lengthened and did not help with being independently active in their future daily lives. The average BI of the 55 conscious patients in this study was 0.6, 33 of them scoring 0 and nine of them scoring 1, which is lower than the 2.1 in the 29 ventilator-dependent patients in Chiang's study [5]. Our results indicate that patients in the RCC usually display a lower degree of mobility. Most of the PT exercises involved a passive range of motion exercises and the upper limbs; however, passive joint exercises had to be incorporated into the program in cases where patients who affected by comorbid diseases, semi-paralysis or being bedridden for a long time, showed signs of declining strength in the lower limbs. Thirty-seven of the patients underwent progressive exercise activities, 30 of them moving into regular wards after weaning from ventilators. Nine of the 30 patients had a BI between 4–12 before being transferred out of the RCC. With telephone monitoring of the progress of mobility after the patients were discharged, only two patients were able to take care of daily chores on their own, while the rest still had to depend on others to perform daily activities.

During the course of ventilator weaning, progress is usually hampered because patients have to breathe harder with a weak diaphragm. Because of the difficulties in breathing, patients tend to use the respiratory accessory muscles, which usually results in a rapid breathing rate. With the intervention of PT that offers exercises and respiratory training, the patients' endurance increases while the difficulty in breathing decreases. PT intervention in patient weaning from ventilators showed no significant outcome according to the results of this study. In general, because of the low consciousness and mobility of the patients in the RCC, only 25% of them were actually able to receive PT for respiratory muscle training and progressed to leave the beds in the PT group. Most of the PT activities included items that were mainly aimed at helping the patients to maintain anatomical stance to avoid spasms or deformities of the body. We suggest that medical teams set up a system of respiratory rehabilitation

plans in which medical personnel may, in addition to individualized medical treatment and weaning plans according to the course of disease, incorporate joint exercises into routine care work at a RCC. PT may be offered to ventilator-dependent patients in line with their individual needs to improve or maintain basic mobility. The purpose is to avoid loose or spastic joints in unconscious patients, as well as to prepare conscious patients to regain mobility for their future lives and return to society. The conclusions of this study will be beneficial to hospital administrators and policy makers with regard to IDS management of respiratory care in prolonged mechanically ventilated patients.

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復健運動在脫離呼吸器與活動能力之成果

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為了解呼吸照護中心呼吸器依賴病人特性和復健治療對於呼吸器脫離及病人活動功能的成效。本研究採前瞻性研究，資料收集 2007 年 7 月 1 日至 2007 年 12 月 31 日 126 位須使用呼吸器 14 天以上之呼吸照護中心住院病人，內容包含 (1) 人口學資料包括性別、年齡、診斷、疾病嚴重度（APACHE II）、改良式昏迷指數（GCS)、住院時活動能力及住院天數；(2) 自呼吸治療紀錄取得之呼吸器脫離指數（RSBI）；(3) 巴氏量表分數（BI）。共有 55 位病人接受復健治療，接受復健治療前後呼吸快淺指數為 75.7 ± 37.9 和 80.0 ± 48.5，巴氏量表於復健治療前後由 0.8 ± 1.4 提升到 1.9± 2.5（$p < 0.05$）。呼吸快淺指數隨著復建時間延長而降低，呈現中度負相關（$r = 0.12$，$p = 0.44$）。接受復健治療者與未接受復健治療者之呼吸器脫離成功率為 58.2% *vs*. 40.9%，隨著復健治療時間延長可提高呼吸器脫離成功率，然而隨著復建時間延長對呼吸照護中心病人之活動能力並無顯著成效（$r = -0.11$，$p = 0.41$）。本研究結果顯示提供呼吸器依賴病人個別需求性之復健治療可以改善或維持病人基本活動能力。

關鍵詞：活動能力，復健治療，呼吸照護中心，呼吸器脫離

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